

A Brief Survey on Human Body Communication for Healthcare Applications



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Abstract

Human body communication (HBC), which utilizes the human body as communication channel to transmit physiological signal, is more reliable and less prone to interference than the wireless transmission techniques such as Bluetooth, Wi-Fi etc. HBC serves as a promising physical layer solution for the body area network (BAN). The human centric nature of HBC offers an innovative method to transfer the healthcare data, whose transmission requires low interference and reliable data link. A brief survey on the development of HBC, which includes the signal propagation mechanisms, channel characteristics and communication performance are summarized and addressed. Moreover, the experimental issues, such as electrodes and grounding strategies are also discussed. Finally, the recommended future studies are provided.

Keywords: Human body communication; Body area network; Signal propagation model; Channel characteristics; Communication performance

Introduction

In the history of human beings, people had great interests on body tissues. Many researchers devoted their efforts and thoughts to investigate the body tissue (i.e. muscle) and their electrical properties and biomechanics. There are generally two

research directions in bioelectrical assessment of muscle, one is to study the electrical signal originated from body tissue, and another is to investigate the properties of tissue by applying electrical signals.

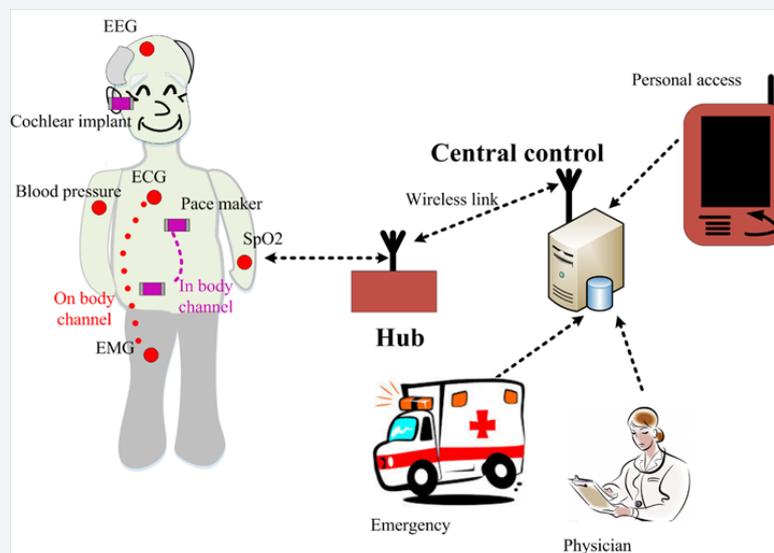


Figure 1: Structure of body area network with HBC.

The connection between electricity and muscle contraction was first observed by the Italian physician Luigi Galvanic in the mid-1780s. Luigi Galvanic found that recently-dead muscle tissue can respond to external electrical stimuli. Since then, more and more researchers investigated the response of human tissue to electric current. The early extensive literature reviews on dielectric properties have been provided by Geddes & Baker [1], who summarized the early reports on the specific resistance of tissues. Later, the intensive research on tissue dielectric property was reported by Gabriel [2]. And further experiments were conducted by Gabriel et al. [2]. To study the dielectric properties of human and animal tissue in the frequency range 10Hz to 20GHz [3]. Basing on these measurements, a parametric model with four Cole-Cole type dispersions was developed to describe the dielectric properties of tissue as a function of frequency [4]. These electrical properties have been utilized by the researchers to facilitate the recent research and applications. For instance, electrical impedance tomography (EIT) has been developed to image the internal organs and structure of body for medical diagnosis, electrical stimulation has been adopted for medical therapy and prosthesis. Until 1995, human body as a transmission medium was proposed to be utilized for data transmission. This type of telemetry, called capacitive coupling HBC [5], was developed to enable data transmission on or around the human body. The development of HBC is background on body area network (BAN), which is introduced in around 2001 and comes to refer the healthcare systems wherein data communication is entirely within the immediate proximity of human body [6]. The deployment of BAN with HBC is shown in Figure 1. The sensor nodes including both the on-body and in-body nodes (implantable devices), perform the monitoring function. The physiological data from these nodes are delivered privately and reliably to a relay node or aggregator mounted on the body, such as a smart-watch or smart wristband. The data are then forwarded to the hub and the central control point, from where the data are available to hospital, professional staff and emergency center or for personal usage. It is expected that the future medical system with BAN can provide the diseases with early discovery, early detection, early intervention and

treatment, which can help to alleviate the prevalence of chronic diseases (e.g. heart diseases, diabetics, strokes) and escalating of aging population, which have become public health concerns and challenges of healthcare system.

Mini-review on HBC

Generally, HBC can be implemented in two ways: capacitive coupling method and galvanic coupling method. Generally, capacitive coupling HBC, which requires ground electrodes floating in air to couple the environment as signal return path, operates in higher frequency around 100MHz to 1GHz, and transmits in longer distance even to 200cm. Galvanic coupling HBC, where all electrodes are tissue-attached, operates in lower frequency around 100kHz to 10MHz, and the attempt to transmit physiological data for implantable devices has been achieved [7].

Development of HBC

The pioneer researches of HBC focused on the feasibility of implementing HBC. After that, the signal propagation models were emerging to investigate the signal propagation mechanism and channel characteristics. Later, experiments and prototypes were developed to investigate their communication performance.

Signal propagation models and communication performance

Since the first attempt of HBC, the signal propagation models, such as circuit models including distributed circuit model [8] and RC model [9], quasi-static model [10], FEM models [11], FDTD model [12] and so on, are proposed by research groups to explain the signal transmission mechanism, which can help to exploit the unknown channel characteristics. The models in the early state consider only the human body and electrodes. Later, the models considering the effect from the environmental effect such parasitic capacitance were developed and then higher matches between model and measurement were achieved. Anyway the discrepancies between the model and measurement results do exist. Reliability of the results that are reported in the published papers may vary, because not all of the issues have been rigorously discussed and verified in the research community.

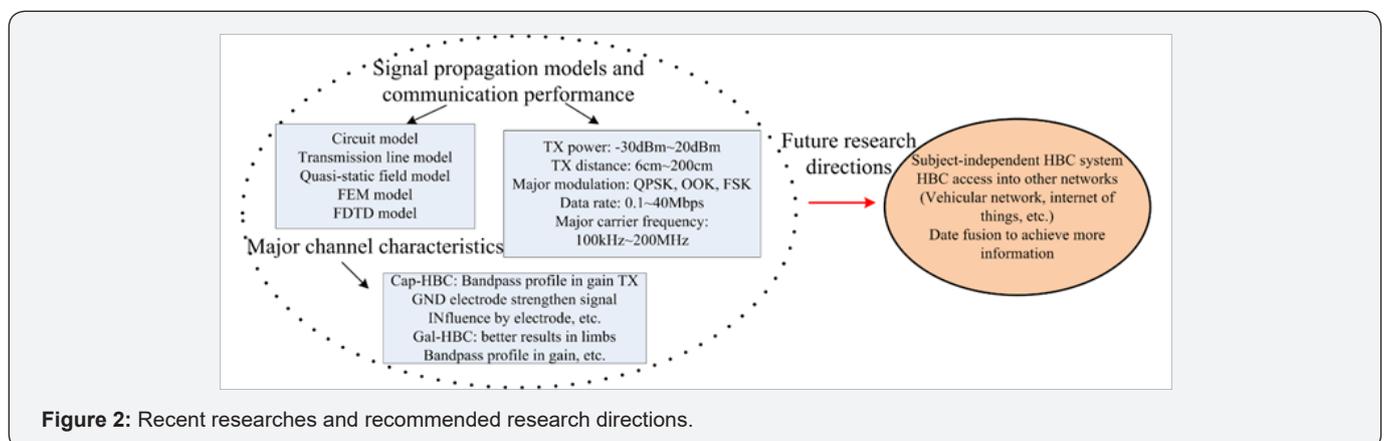


Figure 2: Recent researches and recommended research directions.

Meanwhile, the experimental methods or prototypes are developed to investigate the channel transmission characteristics and communication performance, the suitable transmission parameters for monitoring applications are also investigated in these experiments. The models and communication performance, as well as the future research directions are shown Figure 2. Accompanying with the measurements, the experimental issues such as electrode types (Ag/AgCl electrode, copper electrodes, Pt electrodes), grounding strategies using balun or differential active probes are also investigated in literatures.

Discussion

The new application of HBC in healthcare has also been explored. For instance, galvanic coupled HBC signal propagation has been utilized to evaluate the body fluid [13] and help to aid diagnosis and treatment of fluid disorders such as lymph edema. The human limb galvanic coupled system has been adopted to perform the joint angle estimation [14] which can be applied in prosthesis control and gait analysis.

The measurements show that HBC channel is subject-dependent. To achieve the practical applications, building the reality HBC system with subject-independent is challenged. Moreover, the monitored data in the HBC nodes are raw and rough; it is challenged to fuse these data to achieve in-depth information and deduced information. Moreover, combining the data from multiple sensors such as ECG, blood sensor to achieve a reliable and directly result for the general human is challenging.

Conclusion and Future Studies

Although human body communication (HBC) has been around for more than two decades, we should realize that the technology is still at its infancy. More affects are required to be devoted in the major commercial application of HBC, which is not achieved yet, and there is no feedback from practical applications that usually clarify technical issues that really need to be solved. Therefore, building the commercial HBC system with subject-independent is a recommended research direction. Moreover, developing the HBC model to implantable devices are suggested. Finally, data fusions among HBC nodes to achieve more healthcare informatics are also recommended.

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